Method and arrangement for automatically conditioning analog signals which correspond to different muscle potentials of a living organism

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Abstract of **DE3342549**

The invention relates to a method and an arrangement for automatically conditioning analog signals corresponding to different muscle potentials of a living organism. The analog signals are thereby firstly converted into individual digital signals; the individual signals of groups, consisting in each case of a constant number of individual signals, are stored, after which deviation signals are formed in accordance with deviations of the individual signals of the groups with respect to signals corresponding to the group means; finally, display signals, which are derived from the deviation signals, are assigned to ranges for which the range signals are formed taking account of the frequency of the display signals situated within them. These range signals are then displayed, preferably in the form of a graphic representation.

Computer Assisted Analysis of Electromyographic Data in Diagnosis of Low Back Pain

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Abstract

This paper presents a computerized system to provide expert assistance to a physician in the evaluation of electromyographic findings in the clinical diagnosis of compressive radiculopathies, which has been jointly developed by the Artificial Intelligence Laboratory of the Speed Scientific School, and the Department of Neurology in the Medical School, both at the University of Louisville.

The system uses an object-oriented, frame-based representation of the nerve-root and muscular structure of the lower back and leg, and uses a rule-based reasoning system to interpret electromyographic findings and relate them to potential pathologies in the nerve roots in the lower spinal column.

A novel feature of this research was the development of a hybrid system of Bayesian regulated belief functions and symbolic endorsements for the resolution of uncertainty in the clinical observations. This hybrid system provided quantitative estimates of the nerve pathologies, while simultaneously providing the physician with qualitative information regarding the interrelations of the clinical findings and the diagnosis.

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I. Introduction

Medical diagnosis was one of the early application domains for the expert system paradigm. Four now classic example include the MYCIN system [1] which assists in therapy selection for patients with blood infections, CASNET [2] for glaucoma, PIP [3] for diagnosis of patients with renal disease, and INTERNIST [4] for general internal medicine. This set of examples represents a variety of theoretical approaches to the various tasks of clinical diagnosis, knowledge representation, knowledge acquisition and management of uncertainty. However there are still many open questions about the use of expert system technology in the medical domain, and it continues to be an important focus for investigation.

This paper presents a system for diagnositic evaluation of patients suffering from low back pain taking into account electromyographic finding. Low back pain is a widespread affliction of Americans of all ages. It is one of the most frequent causes for missing work, and is a painful chronic condition for many. It is important to accurately diagnose and treat these conditions. Electrophysiologic techniques have an important role in the evaluation of patients with suspected radiculopathies (compressed nerve root lesions). In the first place, the findings may confirm the presence of a radiculpathy and indicate the level of nerve root involvement. Secondly, the nature of any electromyographic abnormalities may indicate the severity of the underlying pathologic process, which will impact the prognosis for recovery.

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This work uses frames for representation of the basic physiology of the muscles and their associated nerve roots. Characteristics of the nerves and their pathologies as determined by intial physical exams and then by clinical electromyographic data are stored as slot values, and enter into the reasoning process by both forward chaining and backward chaining on a set of production rules. Specifically, forward chaining is used to determine candidate muscle groups for EMG evaluation, and backward chaining is used in the confirmation of nerve root pathologies.

A significant fraction of this research effort was spent in determining and developing the most effective user interface between the physician and the knowledge base. In particular, the clinical observations are entered into the system through a mouse-driven icon panel using the KEE active images feature. The physician can easily explore several tentative diagnoses by modifying these inputs. To manage uncertainties involved with the observation of the clinical data several different approaches were evaluated before settling on a combination of Bayesian updating and symbolic endorsements.

Section II presents a brief overview of the medical knowledge and techniques which are applicable to this problem domain. Section III presents the architecture for the diagnostic system which was developed for use on this problem and Section IV discusses the techniques used for reasoning and uncertainty management. Section V presents the conclusions derived from this work.

II. Medical Knowledge about Back Pain

The lower back consists of the five lumbar vertebrae together with their associated discs, nerve roots, muscles and ligaments. For young people (less than 40 years old) the most likely cause of low back pain is trauma (caused by accident of some type). For middle aged patients (40 to 60 years old), degenerative disc disease becomes increasingly more likely; while for elderly patients (older than 60) osteoporosis (calcium loss) and cancer are also candidates. In any age level it is important for the physician to make an accurate and timely diagnosis so that the proper treatment can be initiated.

A typical diagnostic cycle for suspected radiculopathies consists of four steps. The first step consists of obtaining a patient history and conducting a physical examination of the patient. If the physician suspects nerve root disease, then a series of tests including x-ray imaging of the spine and electromyography (EMG) are ordered. After the tests have been completed the results are sent to the physician for his review in completing the diagnosis.

Most of the work in this research project has centered around the EMG component of the diagnosis cycle, both in the original determination of the number and types of tests to run, and also in the interpretation of the EMG findings in the formulation of the final diagnosis. This component is critical for producing correct diagnoses. The remainder of this section will be devoted to a discussion of the medical knowledge that is involved in selecting the EMG tests and in interpreting the results.

During the initial screening procedure, the physician is interested in obtaining both relevant past medical history, and in performing a set of preliminary tests. In particular the physician is interested in determining the age of the patient, the exact location of the pain, the duration of the symptoms, the extent (if any) of muscle weakness or loss of sensory function, and any past history of injury or surgery. During the physical exam the physician will typically perform at least four standard tests for muscle strength, relex condition, sensory loss, and straight leg lifting. Table I summarizes the indications of the various tests. Based on the results of these tests, and the patient history, the physician makes a preliminary diagnosis, and, if necessary, orders EMG testing.

The EMG testing would usually be done in a hospital or clinic with specialized equipment. Sensing electrodes are mounted on the patient's skin near the desired muscles. The muscles are then stimulated by a special needle, and the resulting signals are recorded, typically on a strip chart recorder. Table II lists the possible abnormalities that may be detected in the EMG patterns, together with heuristic weighting factors for their severity. The analysis of these findings is discussed in the next section.

III. Expert System Design

This section will discuss the expert system that has evolved in the effort to encode the medical knowledge discussed in the previous section. The system uses both frames and rules, and consists of two major components: initial screening and EMG interpretation. The initial screening component uses information from the patient history form, and the preliminary physical examination to formulate a preliminary diagnosis, and to select, if necessary, a set of EMG tests which can confirm the diagnosis. The EMG interpretation section uses the findings from the EMG test to confirm or refute the preliminary diagnosis, and to ascertain the level of nerve root damage.

The logical components of the diagnosic system include both frames and rules. The rule component contains "if – then" production statements about the values of frame slots. The frames component contains physiological connections between the nerve roots and affected muscles, and information about the current patient and diagnosis. Specific instantiations of conditions are stored as slot values in the associated frame. A customized graphic-oriented interface panel is used to elicit information about the current patient from the physician, and this information is stored in the appropriate frame slots.

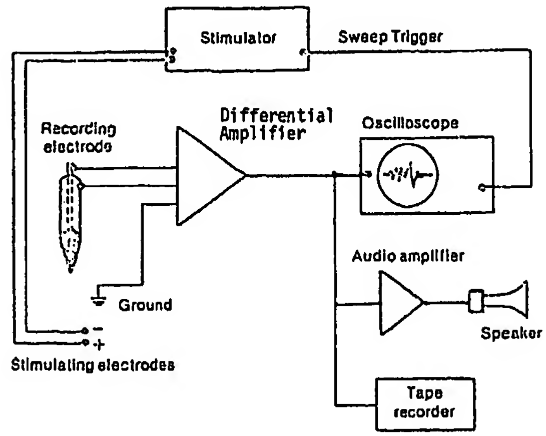

Figure 1 - Components of the Electromyographic System.

Table I - Summary of Low Back Pain Symptoms

Level of Ruptured Disc	Compressed Nerve Root	Reflex Change	Muscular Weakness	Sensory Loss
L3-L4	L4	Knee	Quadriceps knee	Medial
L4-L5	L5	None	Anterior Tibial, Peroneals, and Extensor Hallucis Longus	Lateral Calf, Dorsal Foot and large toe
L5-S1	S1	Ankle	Gastrocnemius	Posterior Calf, Lateral foot,and small toe

Table II - Summary of Electromyographic Results

FINDING	SCORE
a. Fibrillations - frequent	4
b. Fibrillations - rare	3
c. Positive sharp waves - frequent	4
d. Positive sharp waves - rare	3
e. Pseudomyotonia	2
f. Increased insertion activity	1
g. Reduced recruitment - marked	2
h. Reduced recruitment - mild	1
i. Polyphasics, D, A, >50 percentage	3
j. Polyphasics, >20 percentage	2

During the intial phase of selection of appropriate EMG tests, forward chaining is the primary inference paradigm. During the EMG evaluation phase, backward chaining is used exclusively, because of the hypothesis confirmation process that is taking place. Figures 2 and 3 are good examples of the type of inference rules which are used in this system. The final system consisted of approximately 250 rules and over 800 units (classes, members, and facets).

IV. Managing Uncertainty

As with most medical expert systems, the back pain expert system must deal with issues of uncertainty. The major uncertainty in the EMG analysis section arises from the varying degrees of association between muscle reponses and nerve root conditions. For example, the tensor fascia latae is a strong indicator of the condition of L5, but only a weak indicator for L4 and S1.

The intial approach toward uncertainty management was to create a set of belief measures for the various system components, and to update these belief values using the Bayesian-based updating scheme used by Shortliffe and Buchanan in the MYCIN system [1]. Although more sophisticated updating procedures have been discussed in the literature [5-7], the MYCIN approach is computationally simple, and yields acceptable results especially in cases where the inference net is shallow.

Demonstrations and evaluations of the system for the cooperating physicians, resulted in a reevaluation of the belief-based approach for uncertainty management. Physicians, in general, and clinicians, in particular, do not respond well to probabilistic models and reasoning. Although the physicians generally concurred with the values of the belief functions, it became clear that this was not a desirable mechanism from their viewpoint. This led to an implementation of an endorsement based approach for evaluation of EMG uncertainty which will be discussed in the remainder of this section.

The endorsement model used for this work was based upon the ideas expressed by Cohen in [8]. In essence the endorsement system establishes sets of evidence for various diagnostic conclusions which are partially ordered by a set of linguistic variables. A new slot named BELIEF was created in each of the units representing findings which contained exactly one of the following values: strong, less.strong, medium or low. The frames root nerve hypotheses (L1, L2, L3, L4, S1, S2) were augmented by a slot named ENDORSEMENTS to contain a pointer to a list of the rules and muscles which confirm these hypotheses. Finally additional rules and methods were created to evaluate the endorsements, and to manage the resulting lists. A comparison of belief value updating and endorsement updating is given by figures 4 and 5.

V. Summary and Conclusions

This paper has presented the preliminary results in utilizing computer assistance in the analysis and diagnosis of low back pain. Utilizing expert information, a computerized model of the nerve-muscle physiology was developed, and then a set of heuristic production rules was developed and tested to relate this model to clinical findings.

A significant feature of this research was the development of a hybrid system of Bayesian regulated belief functions and symbolic endorsements for the resolution of uncertainty in the clinical observations. In the intial examination, certain qualitative characteristics can be assigned a belief weighting, reflecting the phsician's evalation of the extent of significance. These beliefs are combined by the standard Bayesian updating rules to yield a quantitative assessment of the nerve pathologies involved.

Despite the consistence and apparent precision of the belief function approach, physicians who used this system expressed uneasiness in how to interpret and use this information. This led to the development of the endorsements system to provide secondary evaluation of the clinical evidence and to provide information that can be used by the physician for making his ultimate judgement on the case.

Initial testing of the system has been conducted by Dr. Vasudeva Iyer, the domain expert. Further testing has been somewhat restricted by the absence of a LISP machine on the medical school campus. We are currently investigating an implementation on a PC based shell which would be available for use by medical students, faculty and residents at the medical school. It is hoped that future development of this system will make it suitable for both instructional and clinical use.

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```
(EXTERNAL.FORM
  (VALUE
    ((IF (?NERVE IS IN CLASS LEFT.NERVES)
         (FIND (THE NERVE.AFFECTED
                    OF
                    CURRENT.HYPOTHESIS
                    IS
                    ?NERVE)
              USING
              COMBINATIONS.EMG.LEFT)
        THEN
        (THE NERVE.AFFECTED.LEFT
             OF
             CURRENT.HYPOTHESIS
             IS
             (CAR (GET.VALUES ?NERVE 'NAME)))))
   (INHERITANCE NIL)
   (VALUECLASS NIL)
   (DEFAULT NIL))
```

Figure 2 - Syntax of Backward Chaining Controller

```
(EXTERNAL.FORM
  (VALUE
    ((IF
       (AND (?X IS IN CLASS LEFT.MUSCLES)
            (ALL ?Y ARE PARASPINAL)
            (?X = ?Y))
       (?ROOTS =
               (GET.VALUES ?Y 'ROOT-NERVES))
       (?MUSCLE IS IN CLASS LEFT.MUSCLES)
       (NOT (EQUAL ?MUSCLE ?Y))
       (?Z1 =
            (GET.VALUES ?MUSCLE 'ROOT-NERVES))
       (?INTER =
               (INTERSECTION ?ROOTS ?Z1))
       (LISP (COND ((NOT (EQUAL ?INTER 'NIL)))))
       THEN
       (LISP (UNITMSG 'EMG.METHODS
                      'PARASPINAL.METHOD.LEFT
                      ?INTER))
       (LISP
         (UNITMSG 'EMG.METHODS
                  'RULES.ENDORSEMENT.PARASPINAL
                  ?Y
                  ?MUSCLE
                  ?INTER
                  'PARASPINAL.RULE.LEFT)))))
```

Figure 3 - Syntax of the Paraspinal Rule

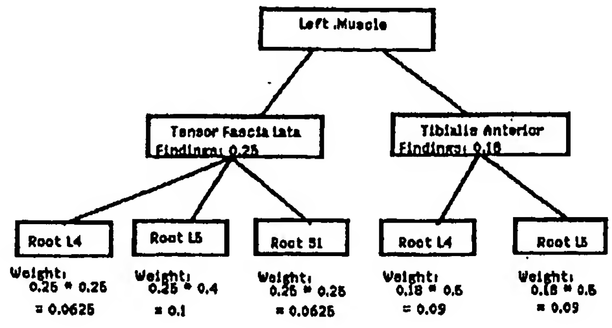

Figure 4 - Belief Value Update

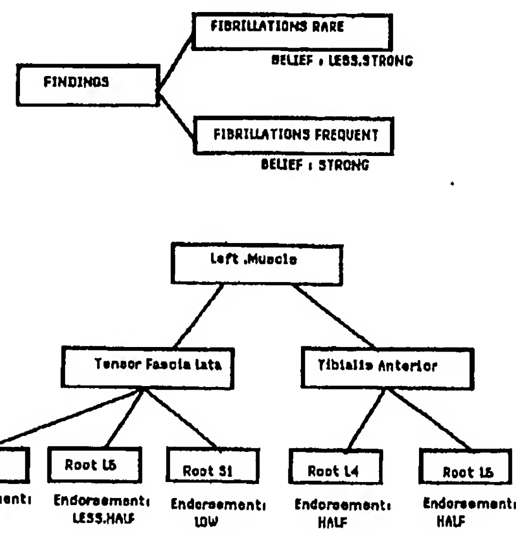

Figure 5 - Endorsement Update